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(54) Drilling tool

(57) The drilling tool comprises a clamping shank, a short transitional portion 4 adjoining same and a substantially cylindrical cutting portion (3) which has two diametrally oppositely disposed flutes (8, 9) which turn through less than 360°, two lands (10) which remain between the flutes and at its front end two replaceable cutting bits (6, 7) which are arranged in mutually displaced relationship through about 180° in the peripheral direction, at different radial spacings from the drill axis (A). The flutes (8, 9) are of decreasing depth, beginning at the front end of the transitional portion to the rear end thereof, and run out into the peripheral surface of the transitional portion at the rear end thereof. The pitch angle of the two flutes (8, 9) increases from the front end of the cutting portion (3) to the rear end thereof. In the rear region of the cutting portion (3) the pitch angle ($\beta 1$) is so selected that at the front end of the transitional portion, where the flutes (8, 9) are still of their full depth, the centre line of each of the two lands (10), which centre line passes through the cross-section at that point (connecting cross-section) of the cutting portion (3), extends substantially in the direction of the overall resultant of the cutting forces acting on the cutting bits (6, 7).

Fig. 1

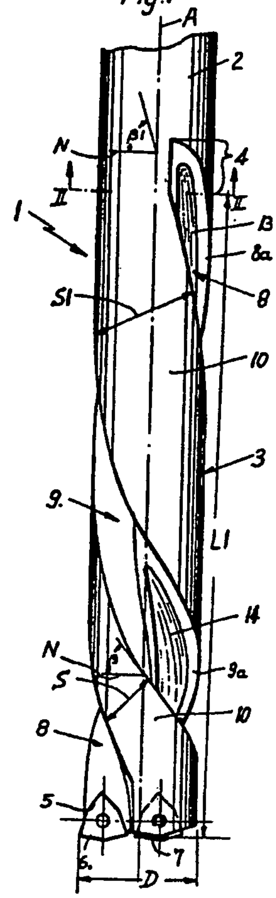

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Fig.1

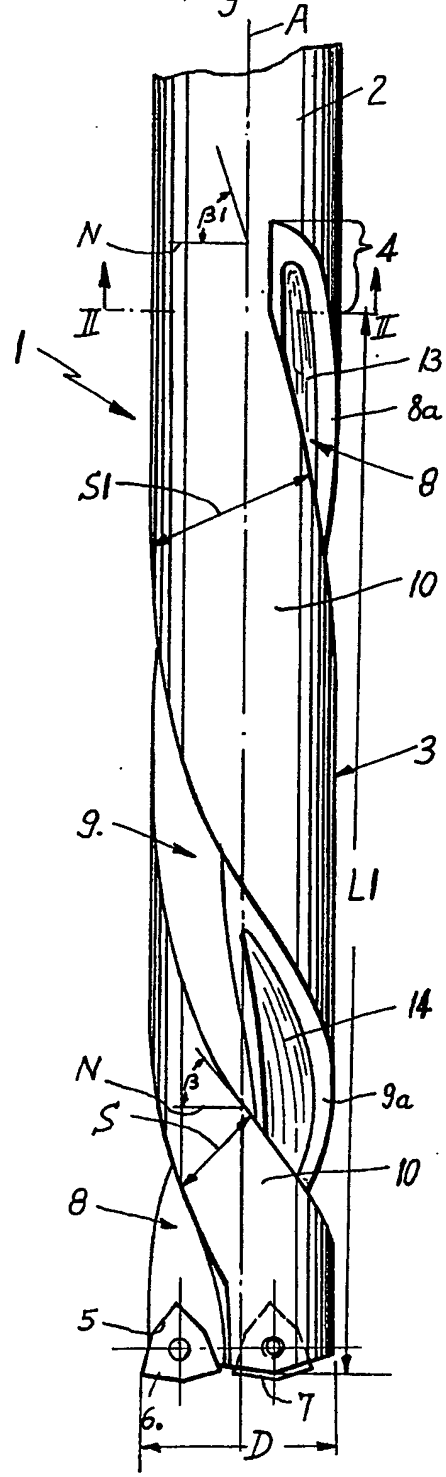
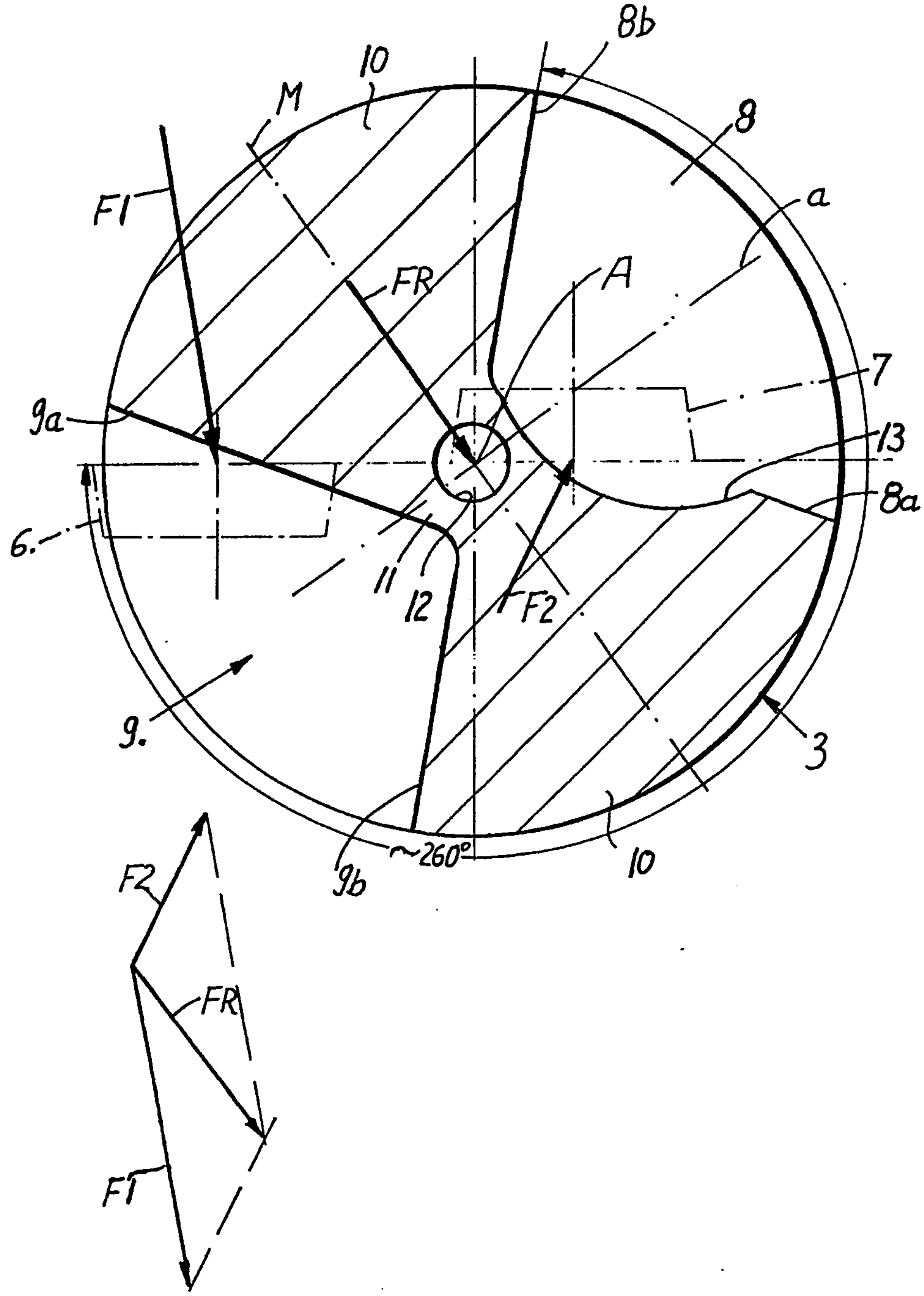


Fig. 2



SPECIFICATION

Drilling tool

The invention relates to a drilling tool having a clamping shank, a short transitional portion adjoining same and a substantially cylindrical cutting portion which adjoins the transitional portion and which has two diametrally oppositely disposed flutes which turn through less than 360°, two substantially diametrally extending lands which remain between the flutes and, at its front end, at least two replaceable cutting bits which are each arranged in a respective recess in the lands and which are arranged in displaced relationship to each other through about 180° in the peripheral direction at different radial spacings from the drill axis, wherein the flutes are of decreasing depth beginning at the front end of the transitional portion towards the rear end thereof and at the rear end of the transitional portion run out into the peripheral surface thereof.

In a known drilling tool of that kind (German utility model No 78 30 277 or the patentees' catalogue 'KOMET KUB Wendeplatten-Bohrer', 9/82, page 12), the flutes have a constant pitch angle. The spiral configuration of each flute extends over about 180°, that is to say about half the circumference of the drilling tool. Drills of that kind are suitable for a depth of drilling which corresponds to about three times the drill diameter. With greater depths of drilling, difficulties may arise in regard to swarf removal and in addition the drilling tools are not sufficiently stiff so that the drill is displaced away from the drilling axis when high cutting forces are involved. Such displacement away from the drilling axis is due to the fact that the cutting forces acting on the radially outer cutting bit which is disposed at the periphery of the drill are higher than the cutting forces acting on the cutting bit which is disposed radially inwardly and which operates adjoining the drill axis. The drilling tool is displaced as indicated above due to the loading on the drilling tool being higher at one side. Such displacement has the result that the drilled hole is of larger diameter than the nominal diameter of the drill and grooves can be formed when the drill is withdrawn, at the wall of the drilling. In spite of a very wide range of proposals for compensating for the forces acting on the cutting bits relative to each other (German laid-open application (DE-OS) No 27 51 255 and European patent specification No 54 913), it has not hitherto been possible to achieve complete balancing in respect of the cutting forces.

The invention is based on the problem of providing a drilling tool of the kind set forth in the opening part of this specification, which, even when used for drilling depths of more than four times the drill diameter, has adequate stiffness and thus a high level of operating accuracy, and which ensures good swarf removal.

According to the invention that is achieved in that the pitch angle of the flutes increases from the front end of the cutting portion to the rear end thereof and that at least the pitch angle in the rear region of the cutting portion is so selected that at the front end of the transitional portion, where the flutes are still of their full depth, the centre line of each of the two lands, which centre line extends through the cross-section at that location (connecting cross-section) of the cutting portion, extends substantially in the direction of the overall resultant of the cutting forces acting on the cutting bits.

As it is not possible to provide that the cutting bits are arranged in such a way that the cutting forces acting thereon completely balance each other out, there is always an overall resultant which tends to displace the drilling tool away from the drilling axis in a given direction. If now in accordance with the invention the two lands of the cutting portion, at the location where the cutting portion blends into the transitional portion, are so arranged that the two lands extend in the direction of the resultant force, then in a region where the maximum bending moment occurs, in relation to a bending axis which extends transversely with respect to the centre line, the cutting portion has the highest moment of inertia in relation to its surface and thus also the maximum degree of stiffness. In order now for the centre line of the lands to be disposed at the correct location, in the case of a drilling tool with a predetermined maximum drilling depth, it is not possible for the pitch of the flutes to be selected at just any angle. In accordance with the invention, the pitch angle of the flutes is to increase from the front end of the cutting portion towards the rear end thereof. At the front end, there is a small pitch angle of preferably about 25° to about 30°, which conveys the swarf away from the region of the cutting bits as quickly as possible. In the rear region of the cutting portion, the pitch angle must now be so selected that the lands and the centre line thereof come to lie at the desired location. The pitch angle may increase in a stepwise manner or continuously, between the front and the rear regions of the cutting portion. Due to the increasing pitch angle, the flutes are also reduced in length in comparison with a drilling tool in which the flutes are of the same pitch angle from the tip of the drill. That means that the distance that the swarf has to cover from the cutting bits to the end of the bore is also reduced and the removal of swarf is improved. If, as is conventional practice, the flutes are produced with an end milling cutter, then the drill has greater land widths, when the pitch increases and the diameter of the end milling cutter remains the same. The

greater land widths then occur at the rear end of the cutting portion and increase the moment of inertia in relation to surface, in that region.

Advantageous embodiments of the invention are characterised in the subsidiary claims.

The invention is described in greater detail hereinafter with reference to an embodiment illustrated in the drawings in which:

Figure 1 is a side view of a drilling tool according to the invention, and

Figure 2 is a view in section taken along line II-II in Figure 1, on a scale four times larger.

The drilling tool 1 comprises a clamping shank 2 with which the drilling tool can be connected to a rotary machine. The actual working portion of the drilling tool is identified as the cutting portion 3, in accordance with DIN 1412. The cutting portion 3 is of a length L1 (referred to as the 'cutting length' in DIN 1412) which, in the illustrated embodiment, is rather more than six times the working diameter D. Accordingly the maximum depth of drilling of the drilling tool 1 illustrated is also six times the diameter. Provided between the clamping shank 2 and the cutting portion 3 is a transitional portion 4 which, in the illustrated embodiment, is of the same diameter as the clamping shank 2 and the cutting portion 3. However, the transitional portion 4 may possibly also increase in diameter conically to the clamping shank 2 so that the clamping shank 2 is also of larger diameter than the cutting portion 3.

Two cutting bits 6 and 7 are arranged replaceably at the front end of the cutting portion 3, in respective recesses 5. The cutting bits 6 and 7 are what are referred to as turnover bits. The two cutting bits are arranged in displaced relationship relative to each other through about 180° in the peripheral direction, the outer cutting bit 6 projecting slightly beyond the periphery of the cutting portion 3 and serving to machine the outer region of the bore while the cutting bit 7 is arranged at the axis A of the drill and machines the inner region of the bore. The working regions of the two cutting bits overlap to a greater or lesser degree, depending on the drill diameter.

The cutting portion 3 further has two diametrally oppositely disposed flutes 8 and 9 which extend in a spiral configuration. The flute 8 is associated with the outer cutting bit 6 and the flute 9 is associated with the inner cutting bit 7. With larger diameters, further cutting bits may also be provided on the same diameter as the cutting bits 6 and 7.

Insofar as the material is not milled away to form the flutes 8 and 9, two lands 10 remain between the flutes 8 and 9, the lands increasing in width in a sector-like configuration in the radial direction from the central core 11. A coolant bore 12 is provided in the core 11. The flutes 8 and 9 are of the same depth over the entire length L1 of the cutting portion 3. From the rear end of the cutting portion or from the front end of the transitional portion 4, the depth of the flutes 8 and 9 decreases continuously to the rear end of the transitional portion 4. At the rear end of the transitional portion 4, where the shank portion 2 begins, the flutes 8 and 9 run out into the peripheral surface of the transitional portion.

The pitch angle β and $\beta 1$ respectively, defined by the flutes relative to a line N normal to the axis of the drill, increases in a stepwise manner or desirably continuously from the front end of the cutting portion 3 to the rear end thereof. At the front end of the cutting portion 3, the pitch angle β, as measured at the periphery, can be about 25 to 30°, while the pitch angle $\beta 1$ is substantially greater at the rear end of the flutes 8 and 9, and is dependent on the parameters referred to hereinafter.

Figure 2 is a view in cross-section through the cutting portion 3 at the rear end thereof or at the front end of the transitional portion 4. At that point the two flutes 8 and 9 are still of their full depth and from there begin to run out in a rearward direction into the peripheral surface of the transitional portion 4. The two diametrally oppositely disposed lands 10 each have a respective centre line M which extends in the cross-sectional plane and which, due to the symmetrical arrangement of the flutes 8 and 9, is a common, diametrally extending centre line M. The surface portions of each land 10 on both sides of the centre line M are approximately equal in size.

Cutting forces act on each of the cutting bits 6 and 7, the positions of which are shown in dash-dotted line in relation to the cross-section shown in Figure 2. The cutting forces act not only perpendicularly to the chip surfaces of the two cutting bits 6 and 7 but also in a radial direction, more particularly generally radially inwardly in relation to the outer cutting bit 6 and generally radially outwardly in relation to the inner cutting bit 7. That gives rise at each cutting bit to a resultant force F1 and F2 respectively, experience showing that the force F1 is approximately twice the force F2. If those two forces F1 and F2 are plotted in a force diagram, as shown at the bottom of Figure 2, that gives an overall resultant FR. In accordance with the invention the centre line M of the lands 10 is now to be arranged in such a way that it extends substantially in the direction of the overall resultant FR, as shown in Figure 2. In that way, in the crosssection where the cutting portion 3 adjoins the front end of the transitional portion 4, the portion 3 has the greatest moment of inertia in relation to its surface, with respect to a bending axis a which extends normal to the centre plane m.

So that the centre line M now extends substantially in the direction of the overall resul-

tant FR and so that the above-mentioned moment of inertia constantly increases from the front end to the rear end of the portion 3, the turn of the flutes 8 and 9 must be less than 360°. In that respect, the pitches in the middle and rear regions of the portion 3 are so selected that the centre line M comes to lie at the desired location which is determined by the direction of the overall resultant FR. The direction of the overall resultant FR can be ascertained either by drawing and calculation or desirably by means of a suitable measuring device (Kistler, 3 -Axis measuring apparatus).

If the flutes 8 and 9 are produced in conventional manner using an end milling cutter, with a pitch angle which increases from the front end of the cutting portion 3, then the result is that what is referred to as the land width S and S1, in respect of the lands 10, increases from the front end of the cutting portion 3 to the rear end thereof. By virtue of that arrangement, the lands 10 of the cutting portion 3 are of their greatest width in the region of the cross-section shown in Figure 2, whereby the moment of inertia of the cutting portion 3 in relation to the surface thereof is still further increased in that region, which also contributes to increasing the stiffness of the drilling tool 1.

Tests have shown that, in the case of drilling tools with the same kind of structure, the direction of the overall force resultant lies, within a certain range of fluctuation, substantially in the same direction in relation to the plane which passes through the chip faces of the two cutting bits 6 and 7. If, in the case of drilling tools of the kind shown in the illustrated embodiment, the spiral configuration of each flute 8 and 9 extends, from the front end of the cutting portion 3 to the front end of the transitional portion 4, over an angular region of about 250° to about 270°, preferably about 260°, then the centre line M is disposed substantially in the direction of the overall force resultant FR.

As already briefly indicated above, the flutes 8 and 9 are desirably produced using an end milling cutter, in which case the drilling tool is rotated and at the same time displaced in its axial direction relative to the end milling cutter. If an end milling cutter of cylindrical form is used, the two flutes 8 and 9 are of the cross-sectional shape shown in Figure 2 in which the two boundary surfaces 8a and 8b, 9a and 9b respectively extend approximately at a right angle to each other. The surfaces 8a and 9a are milled by the end face of the end milling cutter, while the surfaces 8b and 9b are machined by the peripheral surface thereof.

It is now desirable for a groove 13 of segment-like cross-section, which extends over the entire length of the cutting portion 3, to be provided in the surface 8a which extends at the front end of the cutting portion 3 substantially perpendicularly to the plane of the cutting bit 6. The groove 13 is intended to provide that the radially outwardly moving swarf is always conveyed back again towards the interior of the flute 8. In addition the groove is to form the swarf or chip in the front region of the cutting portion 3. The groove 13 further increases the chip space of that flute which is associated with the cutting bit 6 arranged at the periphery. More specifically, that cutting bit produces a substantially greater volume of swarf or chip than the inner cutting bit 7.

A similar groove may also be machined in the corresponding boundary surface 9a of the other flute which is associated with the cutting bit 7 arranged at the axis A of the drill. However the further groove 14 should desirably extend only from the front end of the cutting portion 3 to about one-third to one-half of its length, as shown in Figure 1. In that way the cross-section of the cutting portion is not weakened in its more heavily loaded rear portion, by the provision of the groove 14.

As the volume of swarf or chip produced by the inner cutting bit 7 is smaller, the chip space of the flute 9 is completely adequate.

CLAIMS

1. A drilling tool having a clamping shank, a short transitional portion adjoining same and a substantially cylindrical cutting portion which adjoins the transitional portion and which has two diametrally oppositely disposed flutes which turn through less than 360°, two substantially diametrally extending lands which remain between the flutes and, at its front end, at least two replaceable cutting bits which are each arranged in a respective recess in the lands and which are arranged in displaced relationship to each other through about 180° in the peripheral direction at different radial spacings from the drill axis, wherein the flutes are of decreasing depth beginning at the front end of the transitional portion towards the rear end thereof and at the rear end of the transitional portion run out into the peripheral surface thereof, characterised in that the pitch angle (β, $\beta 1$) of the flutes (8, 9) increases from the front end of the cutting portion (3) to the rear end thereof and that at least the pitch angle ($\beta 1$) in the rear region of the cutting portion (3) is so selected that at the front end of the transitional portion (4), where the flutes (8, 9) are still of their full depth, the centre line (M) of each of the two lands (10), which centre line extends through the cross-section at that location of the tool, extends substantially in the direction of the overall resultant (FR) of the cutting forces (F1, F2) acting on the cutting bits (6, 7).

2. A drilling tool according to claim 1 characterised in that the pitch angle (β) of the flutes (8, 9) is about 25° to about 30° at the

front end of the cutting portion (3) and increases in a stepwise manner or continuously to the rear end of the cutting portion (3).

3. A drilling tool according to claim 1 or claim 2 characterised in that the spiral configuration of each flute (8, 9) extends from the front end of the cutting portion (3) to the front end of the transitional portion (4) over an angular region of about 250° to about 270°, preferably about 260°.

4. A drilling tool according to claim 1 characterised in that each flute (8, 9) has two boundary surfaces (8a, 8b; 9a, 9b) which extend approximately at a right angle to each other and that the flute (8) which is associated with the cutting bit (6) disposed at the periphery, in its boundary surface (8a) which extends at the front end of the cutting portion (3) substantially perpendicularly to the plane of the cutting bit, has a groove (13) of segment-like cross-section, which extends over the entire length of the cutting portion (3).

5. A drilling tool according to claim 4 characterised in that machined in the corresponding boundary surface (9a) of the other flute (9) which is associated with the cutting bit (7) disposed at the axis (A) of the drill is a similar groove (14) which extends from the front end of the cutting portion (3) to about one-third to one-half of its length.

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